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PERFORMANCE ANALYSIS OF CLUSTER ASSEMBLY LINE USING ARENA

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ABSTRACT

The factors which affect the performance of mixed multi -model assembly lines are difficult to be assessed and solved by mathematical model. This paper attempts a practical solution to the stochastic Automobile Instrument cluster assembly line balancing problem. The factors influencing the assembly time in manufacturing systems are analyzed, the Arena simulation model for the above assembly line is built, and the effects of factors on the line balancing problem are considered by simulation tool in the virtual assembly background. Lastly, the balancing results of the deterministic model are compared to the real world data from industries for the validity of the simulation model.

KEYWORDS: Automobile Instrument Cluster Assembly Line, Mixed-Model Assembly Line Balancing, Stochastic Factors & Arena Simulation Model

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Original Article

INTRODUCTION

One of the main problems in the manufacturing industries was line balancing (Roher M. W, 2000; Schaefer D et al., 2001). In the line balancing, the major problem lies in implementation of the set up. It cannot be done in trial and error basis, as its cost involvement is high. The recent development in the field of simulation is one of the best ways to solve this issue. The paper further focuses on the comparison of a real world problem with ARENA simulated model. For this, an automobile instrument cluster manufacturing assembly line is taken. The model is considered as the deterministic model and it is simulated using Arena. The results were compared and the variations in behavior are studied.

RELATED WORK

Elasticity and automation in assembly lines can be attained by the use of robots. For robotic assembly line, the Robotic Assembly Balancing (RALB) problem is definite, also that different robots could be allocated to the assembly tasks, and for all robot needs separate assembly times to do a given assignment, because of its ability and interest. By taking effort for optimal task of robots to the line stations and a balanced supply of work between different stations is the solution for RALB problem. Production rate of the line is increased if the specified problem is rectified. A Genetic Algorithm (GA) is introduced here to find a solution to this problem. For acclimatizing the

GA to the RALB problem, two procedures were introduced, by assigning robots with dissimilar potential to workstations are initiated: a recursive assignment procedure and a consecutive assignment procedure. The results of the GA are enhanced by a local optimization work-piece swap process. Various tests were carried out on a set of randomly produced problems; show that the Consecutive Assignment procedure achieves better solution (Gregory Levitin et al., 2004).

Khouja et al. (2000) implies statistical clustering measures to plan robotic assembly cells. The author introduced two approaches initially a fuzzy clustering algorithm is employed to group similar tasks as one so that they can be allocated to robots as sustain a balanced cell and achieving a preferred production cycle time. In the next stage, a Mahalanobis distance process is used to decide robots suitable for the assignment set is explained by Mahalanobis, 1936; Everitt, 1974. At the same time, as their work focuses on a robotic cell design, it looks for that the approach can be extensive to design of a line of cells with alike cycle times. Though, in an assembly line, task elements may be allocated to a single robot based on the robot potential, and not on task comparison, as considered in their work.

A segregative genetic algorithm for "I"/U"-shaped assembly line balancing problem is presented by the author. It uses a fundamental genetic algorithm and a characteristic function that links a time sketch of the workstations to all chromosomes. The similarity based clustering in the feature space persuades subpopulations of chromosomes. Each subpopulation totally subjugated and sends its centroid to an associative tabu search mechanism. A number of selected new individuals are used to generate clusters that signify new parts of search space. The fatigued subpopulations are replaced by new ones through the evolution. The performance of dynamic segregative genetic algorithm leads to a better trade-off between investigations, made by many clusters, completed by the center on each subpopulation. Experimental result shows that the segregative approach is steadier and analytically produces better results than the basic genetic algorithm (Brudaru, O., 2010).

FACTORS IN THE CLUSTER ASSEMBLY LINE

Various factors which influence the Performance of the assembly lines were as follows (Marecki, F.,(1986); Rosenberg, O., Ziegler, H., (1992); Baybars, I.,(1986); Amen, M.,(2000)

- Task times: In this model, task time is considered as constant, the main reasons for consideration are the model is assumed to be deterministic.
- Manning level: In this deterministic model, for each workstation one labour is employed i.e. manning level is taken as one
- Number of workstations: The number of workstations in this deterministic model is 13. Each station is assumed to be a sub model i.e. it consists of series of tasks.
- Demand rate: The demand rate is taken as 95 Instrument clusters per day for a particular type of cluster. In that, assembly lines there are five lines.

The work elements of each work stations along with their elemental task times are given in Table 1 below:

Table 1: Work Elements and Their Task Times

Cluster Assembly Line:	
	Elemental Task Time
Work station 1 STEPPER MOTOR ASSEMBLY	10
a.Taking PCB from Bin 1:	1
b. Assembling on Fixture 1:	4
c. Taking stepper motor from lot and unpacking the sticker:	2
d. Locating and assembling the stepper motor:	3
Work station 2 STEPPER MOTOR SOLDERING	20
a. Taking assembled PCB with stepper motor from Bin 2:	2
b. Assembling on Fixture 2:	4
c. Taking soldering wire from roll:	2
d. Soldering the stepper motor:	12
Work station 3 LCD ASSEMBLY:	15
a. Taking the PCB with soldered stepper motor from Bin 3:	1
b. Assembling on Fixture 3:	4
c. Taking LCD from lot unpacking the sticker:	5
d. Locating and assembling LCD:	5
Work station 4 LCD SOLDERING	20
a. Taking assembled PCB with LCD from Bin 4:	2
b. Assembling on Fixture 4:	4
c. Taking the soldering wire from roll 1:	2
d. Soldering the LCD:	12
Work station 5 DIAL ASSEMBLY:	10
a. Taking assembled PCB from Bin 5:	1
b. Assembling on Fixture 5:	2
c. Taking the printed dial from Bin.	2
d. Locating and assembling the dial:	5
Work station 6 BACK COVER ASSEMBLY:	15
a. Taking assembled PCB from Bin 6:	2

b. Taking the back cover from Bin:	1
c. Taking the screws from Bin:	2
d. Assembling the back cover with assembled PCB:	10
Work station 7 POINTER DRIVING:	25
a. Taking assembled PCB from Bin 7:	2
b. Taking the pointers from Bin:	3
c. Assembling and fixing the pointers in the assembled unit:	20
Work station 8 AUTO CALIBRATION:	25
a. Taking assembled unit from Bin 8:	2
b. Fixing the assembled unit on Fixture 6:	8
c. Connecting the calibrating unit and testing:	15
Work station 9 CRYSTAL ASSEMBLY:	12
a. Taking calibrated unit from Bin 9:	3
b. Taking the crystal case unit from Bin:	4
c. Assembling the crystal case with calibrated unit:	5
Work station 10 INSPECTION 1 (FUNCTIONALITY CHECKING):	10
a. Taking the assembled unit from Bin 10:	2
b. Fixing the assembled unit to Fixture 7 and checking for functionality:	8
Work station 11 INSPECTION 2 (ILLUMINATION TESTING):	12
a. Taking the assembled unit from Bin11:	2
b. Fixing the assembled unit to Fixture 8 and illumination checking:	10
Work station 12 VISUAL INSPECTION:	10
Work station 13 POINTER FOIL STAMPING:	10
a. Taking the inspected unit from Bin 13:	2
b. Performing printer foil stamping:	8

SIMULATION MODEL ON CLUSTER ASSEMBLY LINE

Simulation is done by using Arena software (Walter Terkaj et al., 2012). In this model, there are 13 workstations and each work station is considered as an individual sub model. In each sub model consists of number of tasks. For example,

consider work station 1, as shown in figure 1 which consists of four tasks,

- Taking PCB from Bin1 is considered as the task 1 which is assumed to have following properties like action is taken as seize delay and release i.e. PCB is taken one by one and it is a non value added activity with a value of 1 minute for doing the task.
- Assembling on Fixture 1 is considered as the task 2 which is assumed to have following properties like action is taken as seize delay and release i.e. PCB is taken one by one and assembling in fixture 1 which is kept at work station 1it is a value added activity with a value of 4 minute for doing the task.
- Taking stepper motor from lot and unpacking the sticker is considered as the task 3 which is assumed to have following properties like action is taken as seize delay and release i.e. stepper motor is taken one by one and it is a non value added activity with a value of two (2) minutes for doing the task.
- Locating and assembling the stepper motor is considered as the task 4 which is assumed to have following properties like action is taken as seize delay and release i.e. locating and assembling the stepper motor in the PCB which is fixed in fixture 1 and it is a value added activity with a value of three (3) minutes for doing the task.

Similarly for all other work stations tasks were defined and simulation model is created as shown in figure 2.

Process - Basic Process

	Name	Type	Action	Priority	Resources	Delay Type	Units	Allocation	Value	Report Statistics
1	Taking PCB from bin 1	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Minutes	Non-Value Added	1	☑
2	Assembling on fixture 1	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Minutes	Value Added	4	☑
3	Taking Stepper motor from lot unpacking the sticker	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Minutes	Non-Value Added	2	☑
4	Locating and assembling stepper motor	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Minutes	Value Added	3	☑

Figure 1: Task Inputs for Workstation 1.

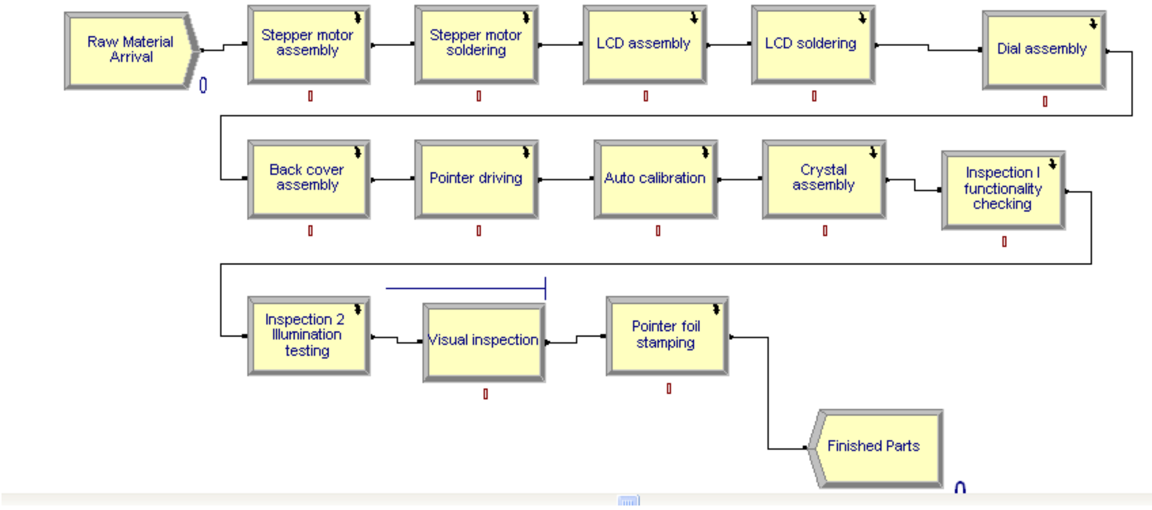


Figure 2: Arena Model of Automobile Instrument Cluster.

Comparison of the Simulation Model Results with the Real World Data

The simulation model is made to run and the results were obtained as shown in table 2. Initially, ninety five (95) work pieces were made as single lot in an assembly line and the results were compared as shown in table 2. The value added time for completing ninety five (95) Instrument clusters were found to be 2.316 hours, Non- value added time for completing ninety five (95) Instrument clusters were found to be 0.9167 hours and waiting time is 46.7547 hours. The total time taken for completing the entire 95 parts is found to be 49.9881 hours. The work in process inventory is found to be 62.772 pieces in total out of ninety five (95) work pieces. In order to compare to real world environment, actually five (5) production lines were in the company. So, per day, each production line operates 1.5 shifts to produce twenty (20) pieces of instrument clusters i.e. each production line in each shift is able to produce 13 to 14 instrument clusters.

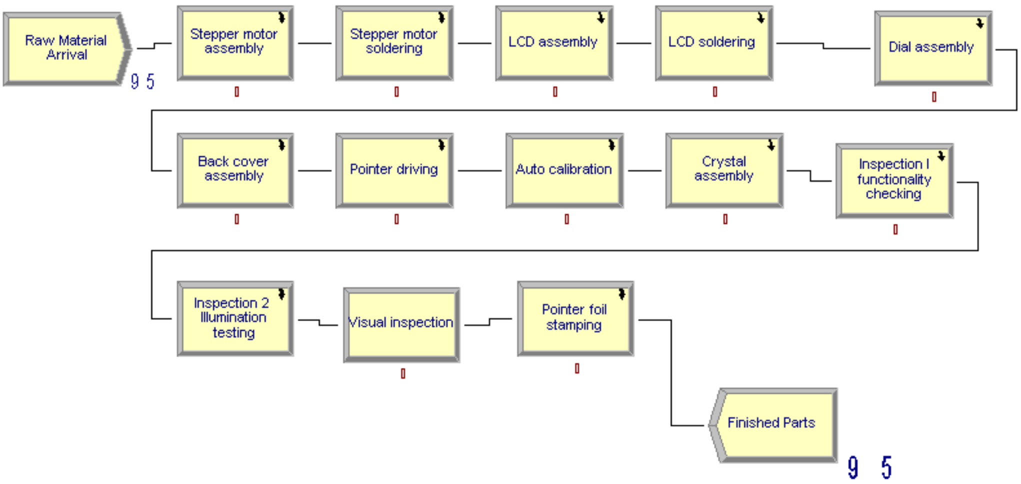


Figure 3: Simulated Arena Model of Automobile Instrument Cluster.

Table 2: Output Results of Simulated Arena Model of Automobile Instrument Cluster

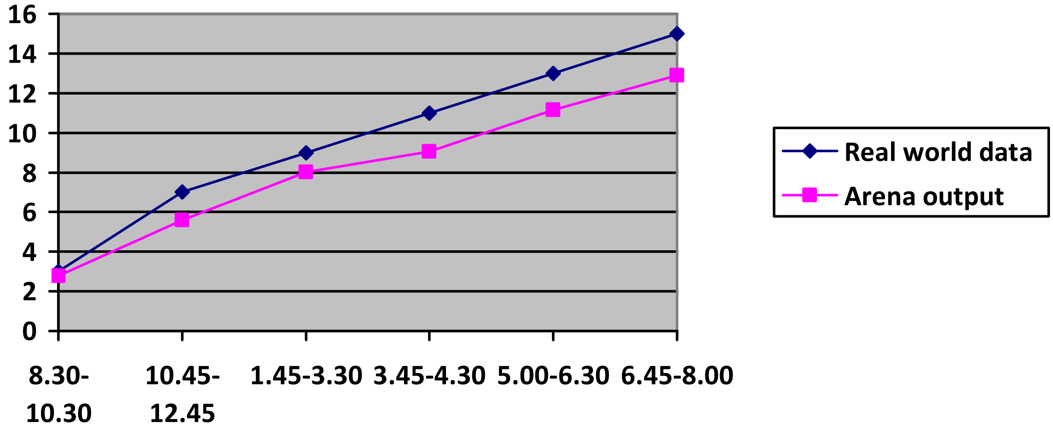
Cluster Assembly Line:		Queue Waiting Time	Instantaneous Utilization
Work station 1	STEPPER MOTOR ASSEMBLY:		0.2093
a.Taking PCB from Bin 1:		0.7833	
b. Assembling on Fixture 1:		3.9167	
c. Taking stepper motor from lot and unpacking the sticker:		4.7	
d. Locating and assembling the stepper motor:		3.9167	
	Total waiting time at WS01	13.3167	
Work station 2	STEPPER MOTOR SOLDERING:		0.4186
a. Taking assembled PCB with stepper motor from Bin 2:		2.4247	
b. Assembling on Fixture 2:		3.8688	
c. Taking soldering wire from roll:		5.1593	
d. Soldering the stepper motor:		6.3309	
	Total waiting time at WS02	17.7837	
Work station 3	LCD ASSEMBLY:		0.3139
a. Taking the PCB with soldered stepper motor from Bin 3:		0.1818	
b. Assembling on Fixture 3:		0.1982	
c. Taking LCD from lot unpacking the sticker:		0.1879	
d. Locating and assembling LCD:		0.1802	
	Total waiting time at WS03	0.7481	
Work station 4	LCD SOLDERING		0.4186
a. Taking assembled PCB with LCD from Bin 4:		0.573	
b. Assembling on Fixture 4:		0.6084	
c. Taking the soldering wire from roll 1:		0.6316	
d. Soldering the LCD:		0.6137	
	Total waiting time at WS04	2.4267	

Work station 5	DIAL ASSEMBLY:		0.2093
a. Taking assembled PCB from Bin 5:		0	
b. Assembling on Fixture 5:		0	
c. Taking the printed dial from Bin.		0	
d. Locating and assembling the dial:		0	
	Total waiting time at WS05		
Work station 6	BACK COVER ASSEMBLY:		0.3139
a. Taking assembled PCB from Bin 6:		0.00754386	
b. Taking the back cover from Bin:		0.00631579	
c. Taking the screws from Bin:		0.00631579	
d. Assembling the back cover with assembled PCB:		0.00157895	
	Total waiting time at WS06	0.02175439	
Work station 7	POINTER DRIVING:		0.5232
a. Taking assembled PCB from Bin 7:		0.6107	
b. Taking the pointers from Bin:		0.6763	
c. Assembling and fixing the pointers in the assembled unit:		0.6163	
	Total waiting time at WS07	1.9033	
Work station 8	AUTO CALIBRATION:		0.7744
a. Taking assembled unit from Bin 8:		1.5532	
b. Fixing the assembled unit on Fixture 6:		1.7589	
c. Connecting the calibrating unit and testing:		1.7874	
	Total waiting time at WS08	5.0995	
Work station 9	CRYSTAL ASSEMBLY:		0.2093
a. Taking calibrated unit from Bin 9:		1.8351	

b. Taking the crystal case unit from Bin:		1.8311	
c. Assembling the crystal case with calibrated unit:		1.6791	
	Total waiting time at WS09	5.3453	
Work station 10	INSPECTION 1 (FUNCTIONALITY CHECKING):		0.2512
a. Taking the assembled unit from Bin 10:		0.02912281	
b. Fixing the assembled unit to Fixture 7 and checking for functionality:		0.02982456	
	Total waiting time at WS10	0.05894737	
Work station 11	INSPECTION 2 (ILLUMINATION TESTING):		0.2093
a. Taking the assembled unit from Bin11:		0.03403509	
b. Fixing the assembled unit to Fixture 8 and illumination checking:		0.01684211	
	Total waiting time at WS11	0.0508772	
Work station 12	VISUAL INSPECTION:	0	0.2093
Work station 13	POINTER FOIL STAMPING:		
a. Taking the inspected unit from Bin 13:		0	
b. Performing printer foil stamping:		0	

CONCLUSIONS

The simulation is also carried out for the production line which operates 1.5 shifts to produce fifteen (15) pieces of instrument clusters i.e. each production line in each shift is able to produce 10 to 11 instrument clusters. And the results were consolidated as shown in Figure 4 below as arena output indicates thirteen (13) clusters can be assembled within 9.4859 hours with value added time of 2.3167 hours, non value added time of 0.9167 hours, waiting time of about 6.2526 hours and total time of 9.4859 hours. The work in process inventory was around 9.787 instrument clusters out of 13 instrument clusters.



X-Axis Time Vs Y-Axis Output

Figure 4: Comparison of Real World Data with Arena Simulated Output.

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